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Evaluation of ERTS-1 Image Sensor
Spatial Resolution in Photographic Form

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Progress Report 5

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Introduction

This report describes progress on this contract during the period 5/1/73 - 7/1/73. Analysis of the first set of image scans is preceeding and the second set of images is being scanned.

Discussion

The first tape of digital microdensitometer data from Mead Technology Laboratories was received near the beginning of this reporting period. About half of this period has been devoted to reading the tape in a form compatible with the CDC 6400 computer at the University of Arizona and to organizing the data into a format convenient for our analysis. The remainder of this reporting period was occupied with preliminary data analysis. Difficulty with locating reference points for the ERTS scans was experienced by the microdensitometer operator, necessitating rescanning of the ERTS material. This problem has been solved and is discussed, along with the preliminary data analysis, in the following sections.

Density Calibration of Microdensitometer

The specular density measured by a microdensitometer is generally different than the diffuse density. The ratio of specular to diffuse densities is defined as the Callier Q factor. The Q factor is always greater than or equal to 1 and depends on the film type and the microdensitometer optical geometry (specifically the numerical apertures of the influx and efflux optics). To facilitate calibration in this situation the microdensitometer electronics can be adjusted to give readings corresponding to diffuse densities of a step tablet made on material identical to the film used for the imagery. If the Callier Q factor is constant over the given density range, this calibration procedure amounts to multiplying the microdensitometer specular densities by a constant (≤ 1) to give the equivalent diffuse densities.

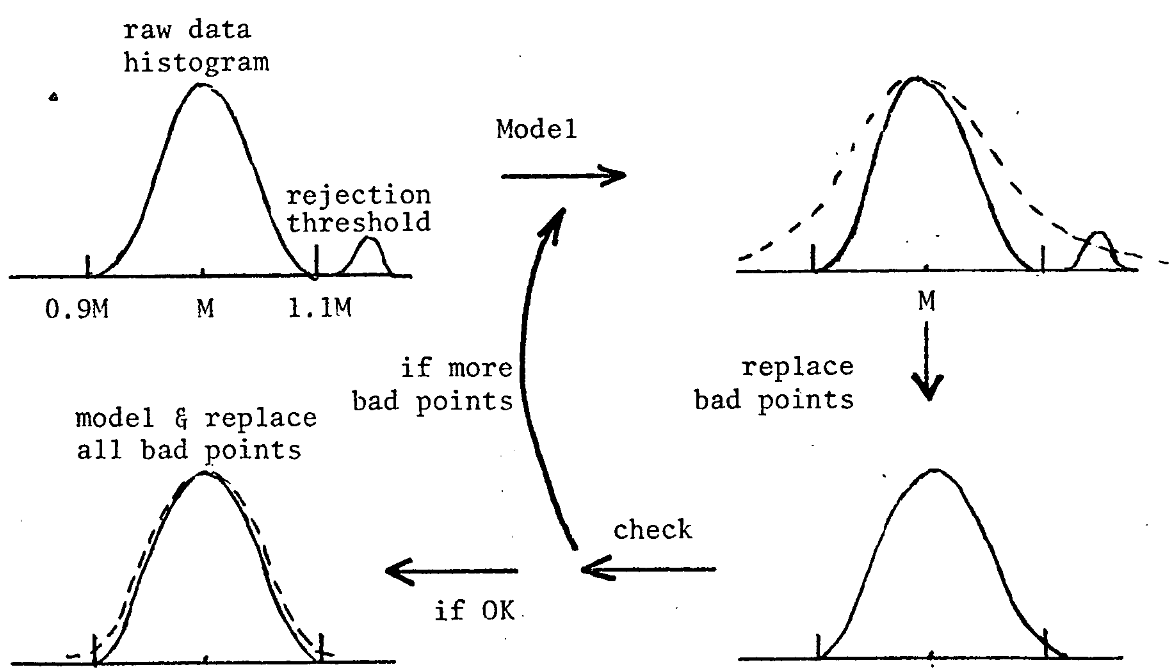
In practice, the instrument is calibrated in this way for a low and high density step in the given step tablet. Figure 1 shows the final calibration for some initial data. It is seen that Callier's Q is nearly constant over the density range, particularly for the A/C film and large microdensitometer slit combination. The microdensitometer densities, being very linear with diffuse densities, permit direct use of the D-log E curve film calibration (excluding adjacency effects) for the microdensitometer readings.

Scan Alignment

Proper alignment of the microdensitometer scans using ground reference points is usually very difficult, especially in the spacecraft imagery. The field of view in a microdensitometer is usually small and cannot be changed easily as with a photointerpreter's microscope. To assure proper alignment, pinholes were made in the imagery at the chosen ground reference points. Using a sharp knife or razor blade,holes of about 20-40 micrometers were produced. Centering accuracy of these holes is estimated to be 10-20 micrometers and is small compared to the slit lengths being used (see Progress Report 4). It is anticipated that these pinholes will assist the microdensitometer operator significantly in achieving correct alignment.

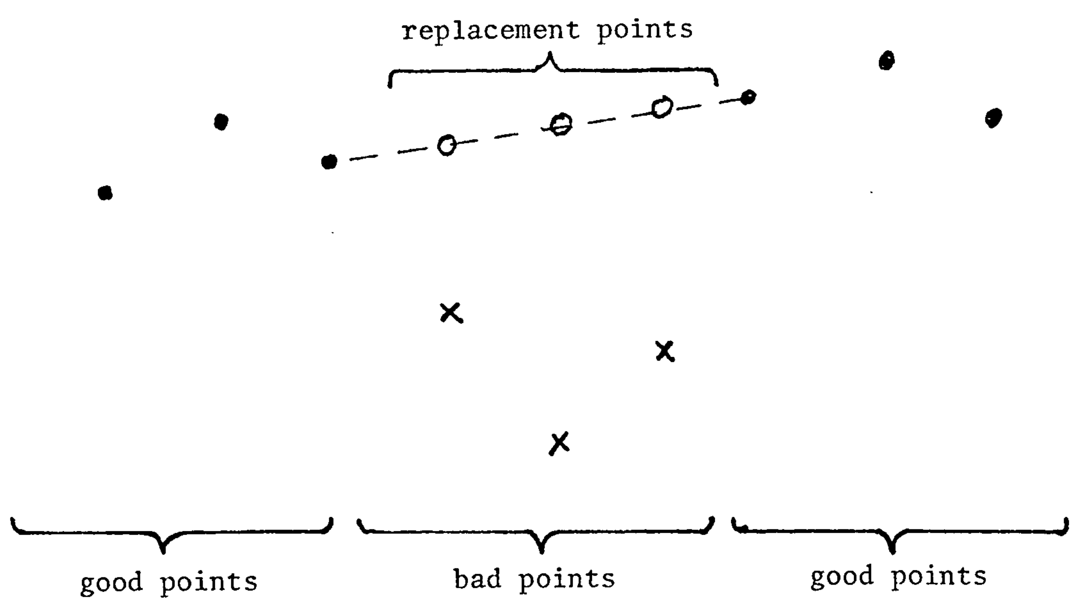
Rejection of Bad Data Points

An automatic computer algorithm has been written to replace bad points (from pinholes, spots, etc.) in the *step tablet scans*. After a first-look at the data histograms a rejection threshold about the mean of ±10% of the mean was chosen as a criterion for replacement. The program models the raw histogram (including bad points) with a Gaussian probability density function of the same mean and variance, and generates random numbers from this pdf to replace any points outside the rejection threshold. The new mean (slightly changed from the original) and new variance (substantially reduced from the original) are calculated and the data, with replacement points, is checked for rejection again. If any bad points are found the process is repeated. When all points are "good" the program replaces once more all bad points found in all interations with random numbers generated from a Gaussian pdf with the most recently calculated mean and variance. Thus it converges on the proper mean and variance. Schematically, the process is,



On initial runs of the program, it was found that usually only one iteration was necessary to correct the bad data. The number of bad points in a record has so far been less than 5% of the total number of points.

Pinholes and spots in the *image scenes* are not as easily correctable as they are in the step tablet scans. These defects are particularly severe in the aircraft imagery, but fortunately the slit is large and tends to reduce their effect. Currently, we are eliminating these points by a tedious manual correlation of analog trace records, digital records, and microscopic viewing of the imagery. The bad points, again a relatively small percentage of the total number, are then replaced by linear interpolation:

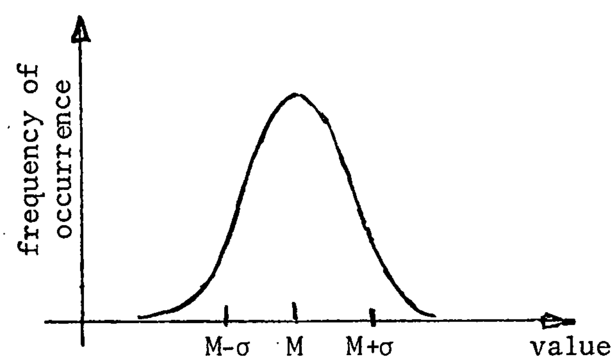


Signal-to-Noise of Scanned Data

In choosing the slit sizes for scanning (see Progress Report 4) it is desirable to select as long a slit as possible to minimize photographic granularity noise. However, one is limited in slit length by the instrument capabilities. Therefore, there is always a finite, possibly negligibly small, amount of noise in the data.

To obtain a feeling for the noise in our data, curves of the standard deviation divided by the mean versus the mean, were plotted for step tablet (i.e. uniformly exposed areas) scans. These are shown in Fig. 1 in both density and transmission units. The significance of these curves is based on the following reasoning.

Suppose a set of measurements are taken from a random process which has a Gaussian pdf with mean, M; and standard deviation σ:



The desired value for the measurement is the mean and, for a Gaussian pdf, 68% of the values are within $\pm\sigma$ of the mean. The *percent error* for measurements in this range is thus,

$$\left|\varepsilon_{rel}\right| \leq \left|\frac{M - M \pm \sigma}{M}\right|$$

$$\leq \frac{\sigma}{M}$$

This is the quantity graphed in Fig. 2 . The percent error of a single microdensitometer measurement will be less than or equal to these values in 68% of the measurements. Likewise, if the ordinate is doubled, the maximum percent error is given for 96% of the measurements.

Figure 2 indicates the microdensitometer scans are essentially free of grain noise. In the range of image values (D = 1.0 - 2.5, T = 0.004 - 0.12) the error is less than 2% in density and 10% in transmission for 68% of the values. The tail at the high density end of the ERTS curve indicates the possibility of another noise source, in addition to granularity, affecting the data.

Current Status of Acquired Imagery

The following table shows the status of imagery required for this program.

Set	Flight Date	Aircraft (A/C) Vinten	Scanner	#frames	ERTS-1 MSS
1	8/22/72	✓	NA	184	
	8/23/72				✓
	(Arizona)				
2	11/29/72	✓	✓*	18	✓
	(San Francisco)				
3	1/4/73	✓**	on order	51	✓
	(San Francisco)				
4	4/4/73	✓	on order	48	on order
	(San Francisco)				
5	Scheduled for 6/15/73	on order	on order		ID not available yet
6	Requested for 9/73 or 10/73				

Data sets 2 and 3 have or are being scanned by Mead Technology Laboratories. It appears that the A/C MSS imagery will be received too late to permit analysis. The quality of the A/C MSS imagery in data set 2 makes its value doubtful in any case. Thus we may be restricted to evaluating bands 4, 5, and 6 only of the ERTS MSS (see Progress Report 3, Fig. 9).

* Scanner data not suitable for analysis because of severe geometric distortion arising from the lack of a gyrostabilized platform on the A/C.

**Band 001 (green) malfunction, no imagery.

Acknowledgements

Mead Technology Laboratories (Dayton, Ohio), an Industrial Associate of the Optical Sciences Center, is performing the microdensitometer scanning for this contract.

Frames Studied

Data Set	Frame #	Bands
2	1129-18181	4, 5, 6

Data Requests Submitted

Date	Frame #'s
6/25/73	1255-18174,-18181,-18183

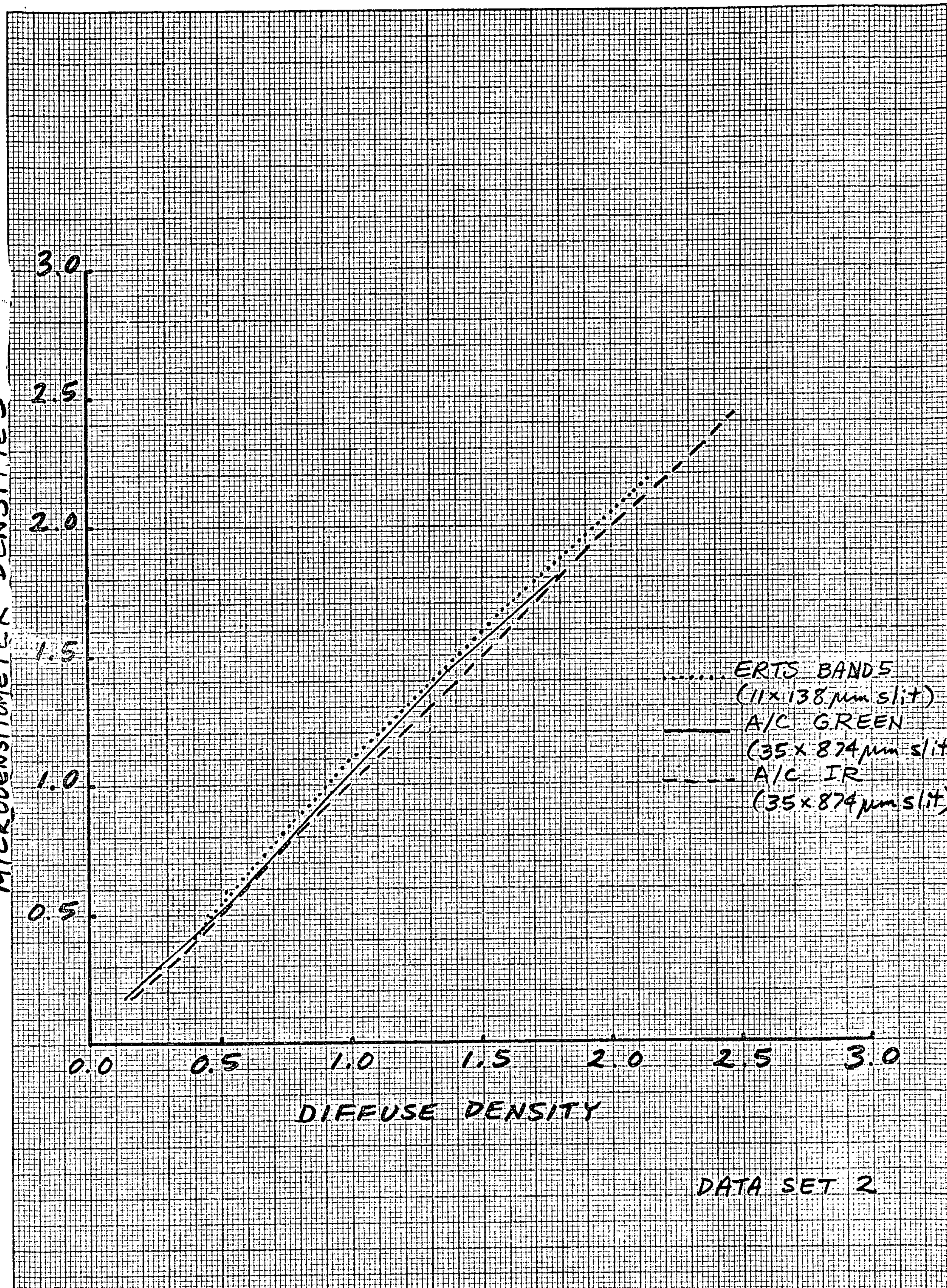


Figure 1

Calibration of microdensitometer

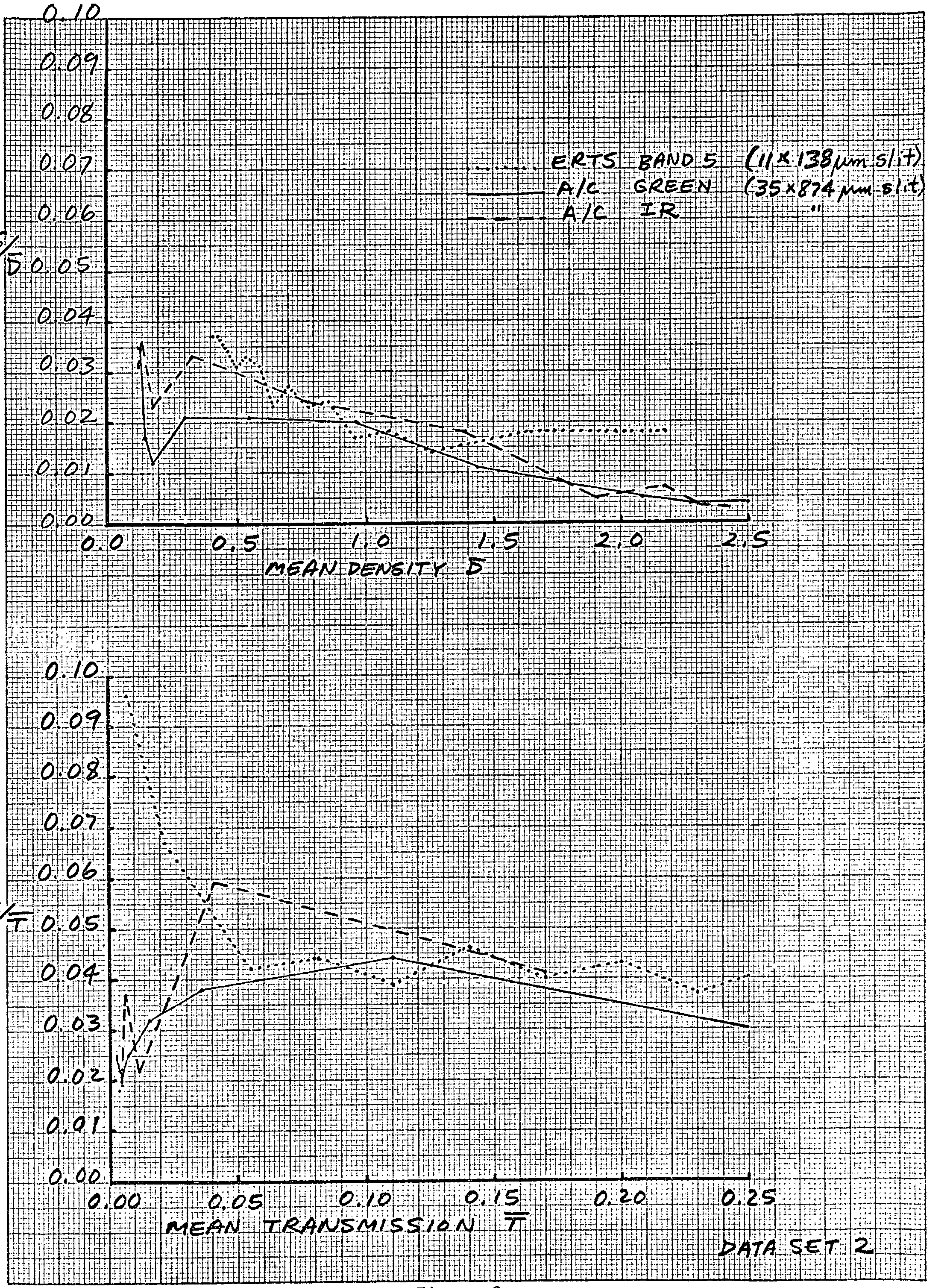


Figure 2.

Percent error in microdensitometer data

REPORT SUMMARY

Evaluation of ERTS-1 Image Sensor

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Type I Report #5

Category 9a - Sensor Technology

This report describes progress on contract number NAS5-21849, during the period 5/1/73 - 7/1/73. Topics discussed are density calibration of the microdensitometer, scan alignment, and signal-to-noise of the scanned data (both aircraft and ERTS imagery). In addition a computer program is described which rejects and replaces bad points , using statistical methods, in step tablet scans.